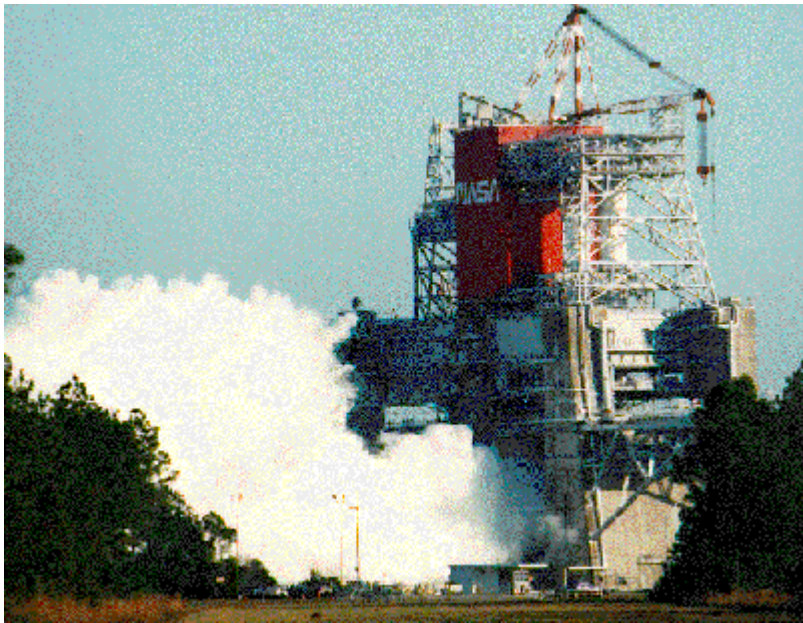




STENNIS SPACE CENTER

The Importance of Ground Testing Information Summary



This "hot firing" of a Space Shuttle Main Engine at NASA's John C. Stennis Space Center is one example of the intensive ground test program performed throughout NASA to ensure that every spacecraft, component and system will withstand the rigors of space. Stennis Space Center is NASA's Center of Excellence for large rocket propulsion systems testing.

Introduction

Before a new type aircraft takes off, a space vehicle is launched or a satellite is placed into orbit, the critical systems of each have been put through an extensive series of Earthbound tests to ensure safe and proper performance.

The value of testing flight systems on the ground becomes even greater when the vehicle contains a

crew and valuable cargo, such as unique satellites and scientific payloads. Ground testing is an essential element in the development of liquid propellant engines because the same item can be static tested and then flown. Confidence in successful flight is increased because the static test closely simulates the flight environment. The more realistic the test conditions and the test item, the more confidence can be placed in the test results since reliability is demonstrated in the testing process. Analysis and theory, even the most detailed, can never adequately replace ground testing. History indicates that a good thorough mix of both analysis and testing is required for success.

In order to make sure that all elements work according to plan, NASA, through several of its field centers around the country, conducts an extensive and ongoing ground test program in which everything from small models to actual aircraft and space vehicles are put through their paces to achieve maximum performance.

Each center has developed highly specialized testing capabilities, equipment and other resources to carry out their precise work.

Three centers--Ames Research Center, Lewis Research Center and Langley Research Center--have wind tunnels and other facilities for testing models and aircraft. At the Johnson Space Center, engineers design and test spacecraft hardware and software in unique facilities. Kennedy Space Center and Goddard Space Flight Center test spacecraft components in various laboratories during launch preparations. Unmanned spacecraft are tested at the Jet Propulsion Laboratory in a facility which simulates the harsh environment of space. As a test and evaluation center for both large and small hardware, the Marshall Space Flight Center has developed unique facilities for simulating the space environment. Stennis Space Center has three massive concrete and steel test stands used to conduct static hot fire tests on Space Shuttle Main Engines. These test stands were originally constructed to test the first and second stages of the Saturn V rocket and were later converted to test Space Shuttle Main Engines. With thrust capability to 15 million pounds, the stands are readily adaptable to accommodate any major propulsion system planned for the future.

All of the centers have individual missions, but they share a common goal of ensuring the safe, reliable performance of new and complex flight systems.

Ames Research Center

NASA's Ames Research Center in California specializes in scientific research, exploration and applications aimed at creating new technology for the nation. The center's major program responsibilities are concentrated in computer science and applications, computational and experimental aerodynamics, flight controls and guidance, flight simulation, aeronautical and space human factors, rotorcraft and powered lift aircraft flight research, life sciences, solar system exploration, airborne science and applications, and infrared astronomy. The center also supports military programs, the Space Shuttle and various civil aviation projects.

Ames is NASA's lead center for supercomputer research. Its supercomputers are the most advanced in the aerospace field. Ames scientists conduct aerodynamics and hypersonic flight research and use supercomputers to solve complex aerodynamic equations to test aircraft designs by simulating aircraft in flight.

Ames' 14 wind tunnels include the National Full-Scale Aerodynamics Complex, the world's largest. The subsonic wind tunnel contains a 40-foot by 80-foot and an 80-foot by 120-foot test section and can test aircraft with wing spans of full-scale aircraft, vertical takeoff and landing aircraft and propulsion systems, and small-scale rotorcraft.

Ames also operates the most advanced flight simulation facilities in the world. The Vertical Motion Simulator is used to test flying characteristics of future concept and operational aircraft, as well as the Space Shuttle. Ames also develops and ground tests flight hardware for future life sciences payloads on the Space Shuttle and Space Station.

Dryden Flight Research Center

The Dryden Flight Research Center in California has unique capabilities to carry out flight research programs. Dryden's main tools are research aircraft, but several ground-based facilities at Dryden play a major role in NASA's total aeronautical research program.

At the Integrated Test Facility (ITF), Dryden personnel ground test highly integrated advanced research aircraft and individual systems. In the ITF, which features six test bays, researchers and technicians safely integrate and preflight aircraft systems such as flight controls, avionics, electrical and other related systems simultaneously before research flights. The ITF capability greatly enhances flight test confidence by giving researchers and engineers the ability to qualify interactive aircraft systems in a controlled environment. Each system within the aircraft can be regulated and monitored in real time as it interacts with the other aircraft systems.

The ITF is data-linked to the Dryden mission control rooms and other facilities. This gives researchers and engineers a real-time comparison of flight and simulation results and allows immediate clearance of flight test points. Simulation systems in the ITF support each major research project at Dryden. They are used for a wide variety of test purposes, such as time histories, redundancy management tests, failure modes and effects tests, pilot evaluation, plus pilot training and flight test planning. The ITF also houses Dryden's ground vibration test systems to measure and test structural frequencies.

In Dryden's Thermostructures Research Laboratory (TRL), engineers and technicians ground test aircraft and structural components and systems to study the effects of individual heat and load conditions. The facility also has the capability of testing new composite materials representative of what may be used to build the next generation of high-speed commercial and military aircraft.

Another unique feature of the TRL is the flow visualization tunnel, which uses water to simulate the flow of air over a model of an aircraft or aircraft component. Also in the TRL is a cryogenic tank, which enables researchers to carry out cold-soak tests of airframe and aircraft systems components. The cryogenic tank will be especially useful if liquid hydrogen is ever used as a propulsion fuel for future aircraft.

Goddard Space Flight Center

Goddard Space Flight Center in Greenbelt, Md., is NASA's first major scientific laboratory. Goddard has evolved into the only national facility that can develop, design, fabricate, test, launch and analyze space science missions using all of its own resources. Since its inception in 1959, Goddard has built and

tested more than 40 spacecraft at its Maryland facility. The unique tests performed at Goddard prior to launch assure that all spacecraft will withstand the rigors of space.

Spacecraft undergo a variety of environmental tests at Goddard, including vibration, acoustics, shock, acceleration, thermal and solar vacuum, temperature and humidity, radio frequency interference, and magnetic fields.

Goddard's specialized test facilities cover a wide range of capabilities. Included among those facilities is the Vibration Facility, which performs shock and vibration tests on spacecraft and subsystems, reduced test data and calibrates transducers. In the Battery Test Facility, tests of aerospace batteries and cells are performed under simulated space environmental temperatures, and in the Large Area Pulsed Solar Simulator, solar cells and panels are irradiated with simulated solar radiation. All standard tests on electrical insulations for space use are tested in the High Voltage Testing Facility. Also, a Magnetic Field Component Test Facility is used to calibrate and align magnetometers, while the Spacecraft Magnetic Test Facility checks out spacecraft, sounding rockets, attitude control systems, magnetometers and subsystems.

In other areas, the High Capacity Centrifuge simulates launch and landing loads on spacecraft hardware, and a Space Simulation Test Facility contains thermal vacuum test chambers with different dimensions and environmental capabilities. Also, various-sized scientific satellites, sub-systems and components are tested in the Acoustic Facility containing a reverberation chamber, acoustic horns, noise generators, control console and a data handling system. In addition, two electromagnetic interference test facilities are available for proving spacecraft and scientific instruments worthy for flight.

The Wallops Flight Facility, which is part of the Goddard Space Flight Center, manages and implements NASA's sounding rocket projects, which use suborbital rocket vehicles to accommodate approximately 30 scientific missions each year. These sounding rockets provide data on the Earth's environment and also advance technology in such areas as communications and meteorology. Two facilities provide testing--a Dynamic Balance Facility and an Environmental Testing Laboratory.

The Dynamic Balance Facility at Wallops Island in Virginia offers a means for dynamic and static balancing of sounding rockets, probes, and re-entry and orbital vehicles to assure proper flight performance and stability.

The Environmental Testing Laboratory provides for the testing of sounding rocket payloads, subassemblies and instrumentation.

Other testing at the Wallops Facility involves electrical systems, attitude control and boost guidance of the sounding rockets.

Jet Propulsion Laboratory

The primary missions of the Jet Propulsion Laboratory in California are the design, development, testing and operation of deep space flight spacecraft, instruments and associated ground systems.

Flight spacecraft and instruments are tested in clean room test facilities with rigorous control over particulate and volatile contaminants to preserve the capability of the sensitive sensors. Test facilities

include the Spacecraft Assembly Facility, which has two high bays capable of maintaining class 10,000 clean room operations, and an adjacent support equipment area. Other smaller clean rooms are maintained for the support of flight instruments.

A complete environmental test capability is available for testing flight hardware. The 25-foot solar thermal vacuum test chamber provides high quality space simulation for testing spacecraft under conditions of extreme cold, high vacuum and highly uniform collimate solar radiation. Numerous other smaller chambers are also available for testing flight subsystems and instruments. A dynamic test facility provides the capability for testing dynamic balancing, dynamic simulation, vibration acoustics and shock systems, ranging from small instruments to complete spacecraft.

A launch support capability is maintained at Cape Canaveral Air Force Station to support launch operations at Kennedy Space Center.

Extensive support is maintained for testing the ground systems software required for spacecraft testing, ground data systems testing, and Deep Space Network integration and testing. These facilities and systems require extensive computer systems support and continuous maintenance and upgrade.

Lyndon B. Johnson Space Center

Johnson Space Center designs, develops and tests spacecraft and associated systems for manned space flights. Astronauts train through simulation activities covering all phases of a mission, from liftoff to landing. The center also operates the White Sands Test Facilities in Las Cruces, N.M., where propulsion systems tests are conducted.

Although better known for its role in manned space flight, the Texas-based center ranks as one of the nation's leading software production facilities. With four major software labs, JSC is at the heart of a software community which produces, checks and uses the complex shuttle computer codes.

There are two phases of operational increments, or versions, during which new capabilities or enhancements are added to the software code. This takes place primarily in the Software Development Facility. The second phase is reconfiguration, during which mission-unique data are applied to the base software systems to tailor them for specific flights. This phase occurs in the Software Production Facility. Validation of the software is of critical importance since every function of the orbiter is driven by computers.

In the final stages of readying for a mission, the flight software undergoes integrated performance tests in the Shuttle Avionics Integration Laboratory, another of JSC's major computer validation facilities. This lab precisely duplicates, from end-to-end, all avionics hardware used aboard the shuttle.

In addition, the software is loaded in the Shuttle Mission Simulator, the fourth principal software checkout facility. Both nominal and off-nominal runs are executed by flight crews for each mission.

At the White Sands facilities, there are five operational propulsion test stands. Three of these have altitude simulation capabilities which allow propulsion systems testing to be performed in a sustained near-vacuum environment. The remaining two stands are ambient, or open, stands.

John F. Kennedy Space Center

Kennedy Space Center in Florida is NASA's primary launch center, and most ground test functions are geared toward launch operations. Both vehicles and payloads, usually complex spacecraft, must be extensively tested prior to being certified ready for flight.

Spacecraft are usually fully assembled and thoroughly tested in the plant of the manufacturer before being disassembled and shipped to KSC. There are five facilities where the smaller spacecraft, or "vertically processed pay- loads," are first reassembled and then thoroughly ground tested. Four of these are on Cape Canaveral, and one is in the industrial area of KSC. Each facility has one or two clean rooms, which provide an ultra-clean environment. Testing usually involves some interaction with the communications and other systems which support all launches. Compatibility checks with the launch vehicle, including physical fit, electrical and mechanical connection checks and support system functions are a routine part of ground testing operations.

The largest spacecrafts, such as Spacelabs and the Long Duration Exposure Facility, called "horizontally processed payloads," are assembled and ground tested in the Operations and Checkout Building. Components for the International Space Station, which will also be large, will be tested and assembled into launch-ready payloads in the new Space Station Processing Facility. Testing of both types of payloads can continue, on a reduced scale, right up to launch.

The assembly and ground testing of Space Shuttle vehicles is the largest single responsibility of KSC. The launch itself is considered the final "test" at the end of a long series. The major shuttle components--the orbiter, solid rocket boosters and external tank--are tested and partially assembled in different facilities. Of these components, the orbiter is by far the most complex and difficult to ground test and prepare for flight. Much of the testing is performed in the Orbiter Processing Facility, a hangar-like building designed to support orbiter assembly and test functions. Most test operations are controlled by the computerized Launch Processing System.

Langley Research Center

The Langley Research Center in Virginia has been instrumental in shaping aerospace history for more than seven decades. Today the center remains dedicated both to serving traditional aerospace customers and to transferring aerospace technology to nontraditional aerospace customers in response to changing national priorities. Langley's long history of direct partnerships with industry readily fits the nation's goal of capitalizing on federal laboratories to enhance economic competitiveness.

Langley's primary mission is basic research in aeronautics and space technology. Research fields include aerodynamics, materials, structures, acoustics, flight systems, information systems, spacecraft analysis and atmospheric sciences.

More than half of Langley's effort is in aeronautics, working to improve today's aircraft and to develop concepts and technology for future aircraft. More than 40 wind tunnels, other unique research facilities and testing techniques, as well as computer modeling capabilities, aid in the investigation of the full flight range--from general aviation and transport aircraft to hypersonic vehicle concepts.

One Langley goal is to develop technologies to enable aircraft to fly faster, farther and safer and to be

more maneuverable, quieter and less expensive to manufacture and more energy efficient. For example, researchers are studying improved airborne systems to aid aircraft in operating more efficiently in all kinds of weather and in crowded terminal airways. Langley is transferring to industry what it has learned about wind shear, the cause of nearly 40 percent of U.S. airline fatalities in a recent several-year period.

Langley is the lead center for management of the agency's technology development programs for future High-Speed Civil Transport, for hypersonic vehicle concepts and for general aviation.

Lewis Research Center

The Lewis Research Center in Ohio is NASA's lead center for aeronautical propulsion, space power, space communications, space electric propulsion systems and microgravity science.

Lewis' facilities include vacuum chambers, which simulate operating environments for complete systems, altitude chambers for aircraft engines, a tunnel to simulate aircraft icing conditions, supersonic wind tunnels, space simulation chambers for electric rockets or spacecraft, and 79-foot deep and 430-foot deep drop towers for microgravity research. The center also has a variety of engineering test cells for experiments with components such as compressors, pumps, conductors, turbines, nozzles and controls.

The center's 10-foot by 10-foot Supersonic Wind Tunnel is home to the development of leading-edge aeropropulsion technologies that contribute to the global preeminence of the U.S. aeronautics industry. This facility has tested scale models of the nation's aircraft, rocket boosters, upper stage launch vehicles, nose cones and even full-scale aircraft engines. This wind tunnel plays an essential role in the High-Speed Civil Transport Program, a Lewis-led program to develop the next generation of supersonic aircraft.

Lewis' Icing Research Tunnel is the world's largest refrigerated icing tunnel, capable of duplicating the conditions encountered by aircraft by controlling liquid water content, droplet size and air temperature within the tunnel. Throughout its 50-year existence, the icing tunnel has been used to test many aircraft deicing/anti-icing fluids. Icing is no longer a major problem for many of today's aircraft because of the ice protection systems technology largely developed at Lewis.

Lewis' Plum Brook Station, located near Sandusky, Ohio, also boasts world-class test facilities, including the world's largest space environment and the world's largest vacuum chamber, the United States' largest space environment test chamber for full-scale rocket engine testing, a cryogenic propellant tank facility, and the United States' only large nonvitrated hypersonic wind tunnel.

George C. Marshall Space Flight Center

Alabama's Marshall Space Flight Center facilities provide a capability for simulating space environment, testing large systems, and developing new materials, hardware and procedures. The center has engineering test facilities for material, components and system development, including thermal/vacuum chambers, material environmental evaluation facilities, cryogenic facilities, fluid/gas flow facilities, and numerous propulsion test facilities.

The Neutral Buoyancy Simulator, NASA's largest such tank, offers an underwater environment for

testing hardware to examine how it will operate in space and for evaluating techniques for space construction and spacecraft servicing.

The MSFC Flight Robotics Facility is a test and simulation facility for developing remotely controlled systems such as free-flying satellites, manipulators and robots.

The Drop Tower and Drop Tube Facilities provide more than four seconds of free fall that simulates weightlessness, during which materials are processed and fluid behavior is examined.

The X-ray Calibration Facility simulates X-rays from distant celestial objects to measure the efficiency and image quality of an X-ray instrument.

John C. Stennis Space Center

Stennis Space Center in South Mississippi is NASA's primary center for testing large rocket propulsion systems for the Space Shuttle and future generation space vehicles. Because of its important role in engine and vehicle testing over the past three decades, SSC is NASA's Center of Excellence for large rocket propulsion systems testing.

A primary mission of SSC is to support the development, certification and acceptance testing of Space Shuttle Main Engines. The task of firing the engines is accomplished by securing them individually in one of Stennis Space Center's concrete and steel test stands, where a series of test firings is performed. The engines are then shipped to the Kennedy Space Center for installation on an orbiter.

During these tests, the engines are "hot fired" for various durations under different operating conditions to determine their flight worthiness. The data accumulated from these ground tests, which simulate flight profiles, are analyzed to ensure that engine performance is acceptable and that the required performance will be delivered in the critical ascent phase of shuttle flights. In the process, NASA is able to verify design changes, develop components and resolve any problems in the engines before they are put in the actual flight situation. Shuttle engine tests at Stennis fall into the following categories: development, flight certification, margin demonstration, life extension, and flight acceptance.

In addition to its active SSME Test Program, Stennis Space Center is taking strides toward the future testing of large rocket boosters, stages and components. SSC's Component Test Facility is capable of rocket engine and/or engine component testing and is flexible in that it can accommodate both large and small rocket engines and components.

Stennis Space Center's research engineers also use the Component Test Facility to advance knowledge in test technology areas such as instrumentation, engine exhaust plume analysis, test facility design and evaluation, and data acquisition.

In support of hypersonic aircraft of the future, a High Heat Flux Facility is located at SSC. This facility gives the space center the capability to perform tests on large-scale surface sections of materials exposed to high temperatures during flight.

Through its Advanced Program Development Office, SSC is now conducting cooperative testing programs in partnership with U.S. aerospace industry. Stennis' unique test facilities are available to

support the national interest in propulsion systems development testing.



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